

Accelerated Insertion of Materials - Composites



Presented at Mil-Hdbk-17 Forum

by Tony Caiazzo

Materials Sciences Corporation

215-542-8400, ext 331

tony@materials-sciences.com

26 February 2003

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AIM-C Alignment Tool



The objective of the AIM-C Program is to provide concepts, an approach, and tools that can accelerate the insertion of composite materials into DoD products

AIM-C Will Accomplish This Three Ways

Methodology - *We will evaluate the historical roadblocks to effective implementation of composites and offer a process or protocol to eliminate these roadblocks and a strategy to expand the use of the systems and processes developed.*

Product Development - *We will develop a software tool, resident and accessible through the Internet that will allow rapid evaluation of composite materials for various applications.*

Demonstration/Validation - *We will provide a mechanism for acceptance by primary users of the system and validation by those responsible for certification of the applications in which the new materials may be used.*

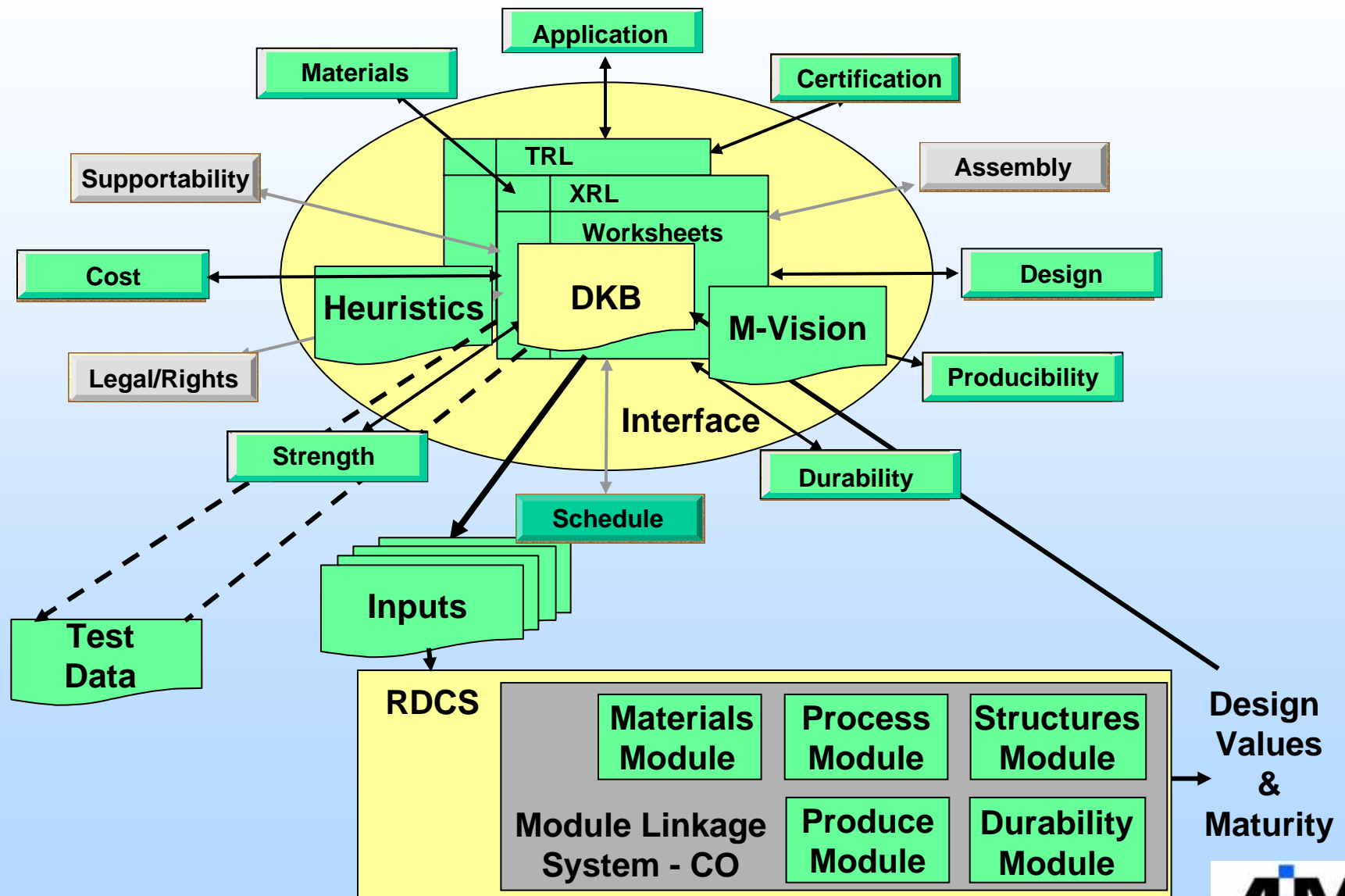


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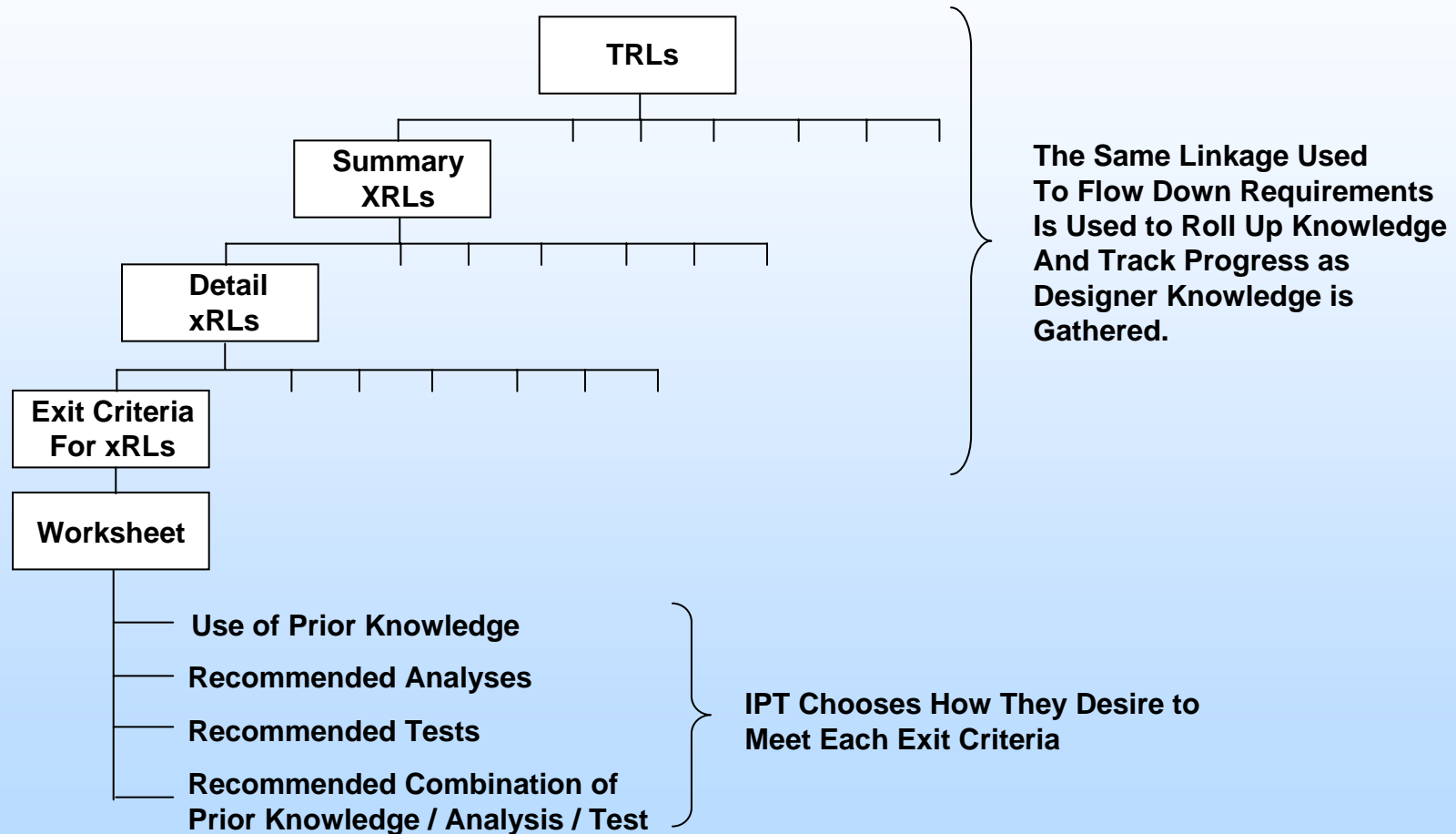


AIM-C System Vision





AIM Methodology Becomes a Requirements Flow Down and a Completion Roll Up



AIM-C Transition Plan

February 2001

February 2002

February 2003

February 2004

AIM Product
Development

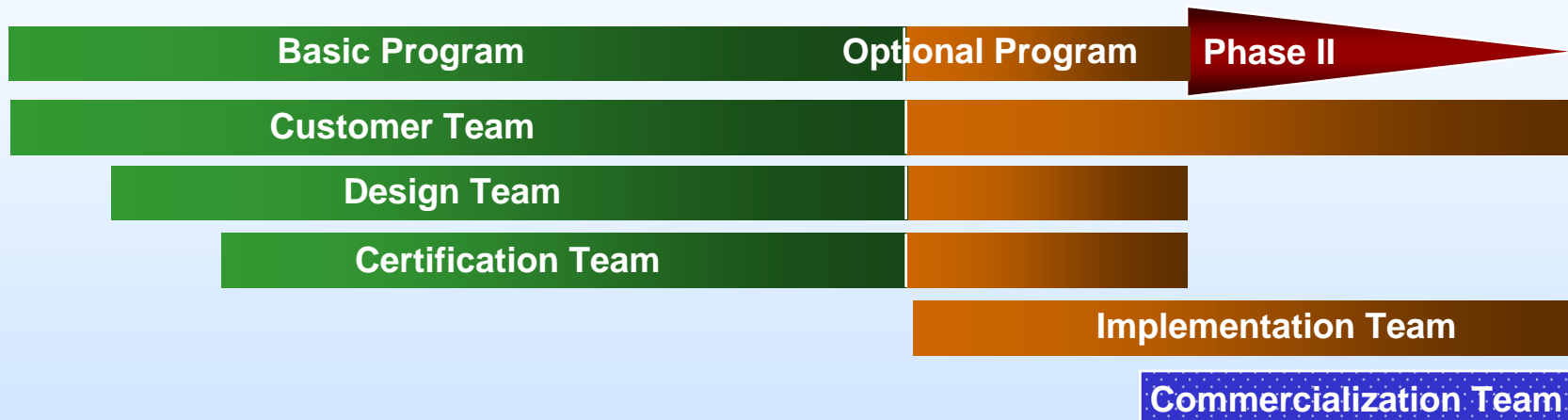
AIM Product
Verification

AIM Product
Demonstration

AIM Product
Refinement

AIM Product
Validation

AIM Product
Implementation



Customer Team – To ensure that the product meets the needs of the funding agents

Design Team – To ensure acceptance among users in industry

Certification Team – To ensure acceptance among the certification agents for structures

Implementation Team – To ensure acceptance among the user community

“Commercialization” Team – To ensure support of users

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CC30033.01




AIM-C Certification Team



Agency	Integration	Structures	Materials	Producibility
Boeing	Charley Saff	Eric Cregger	Pete George	John Griffith
Navy	Don Polakovics	Dave Barrett	Kathy Nesmith	Steve Claus
Air Force	Tim Jennewine	Dick Holzwarth	Katie Thorp	Bob Reifenberg
FAA	Curt Davies	Larry Ilcewicz	David Swartz	Dave Ostrodka
Army	Mark Smith	Jon Schuck	Marc Portanova	Steve Smith
NASA	Mark Shuart	Jim Starnes	Tom Gates	Tom Freeman

To Insure That the Methodology, Verification, and System Validation We Do Satisfies Certifying Agencies



AIM-C Main Menu

Alpha Minus Version [Help](#)

- Home
- Setup DKB
 - Applic
 - Certifi
- Sign Off Requirement
- Edit DKB
 - TRL
 - Chart
 - Applic
 - Certifi
 - Desig
 - Asser
 - Struct
 - Mater
 - Fabric
 - Cost
 - Suppe
 - Intelle
 - Rights
 - TRL
 - Sched
 - Legal
 - Legac
 - Inform
 - Additi
 - Input
 - Demo
 - 1
 - Comp
 - Mesh

Designer's Knowledge Base

Coefficient of Thermal Expansion

Thermal Expansion Properties are Reported as a Function of the State Properties Degree of Cure, Temperature, and Moisture Content

Resin

Fiber

State Variables

Degree of Cure

Temperature

Moisture Content

Layup Definition

Calculation Method

Export to CSV

Link to Model

1. Hexcel IM7

2. Hexcel AS4

1. 0/90, +/-0

2. Carpet Plot

3. Unidirectional

4. Custom Defined

1. CAT (Linked Modules)

2. From Data Base

Property To Display

1. Alpha x vs. Layup

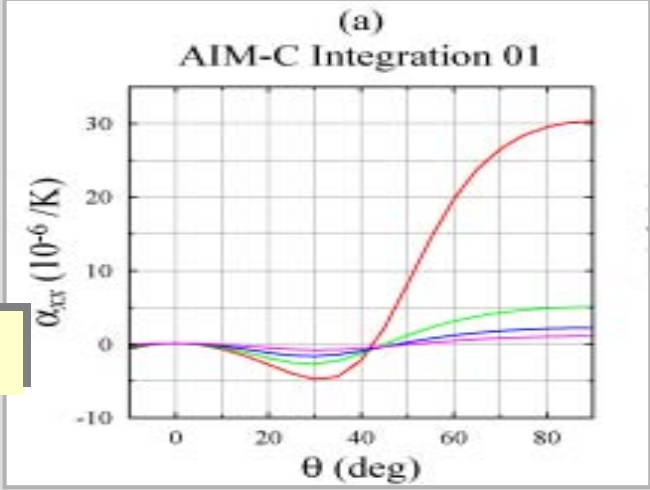
2. Alpha y vs. Layup

3. Alpha z vs. Layup

4. Alpha x vs. T at a Given Theta

5. Alpha y vs. T at a Given Theta

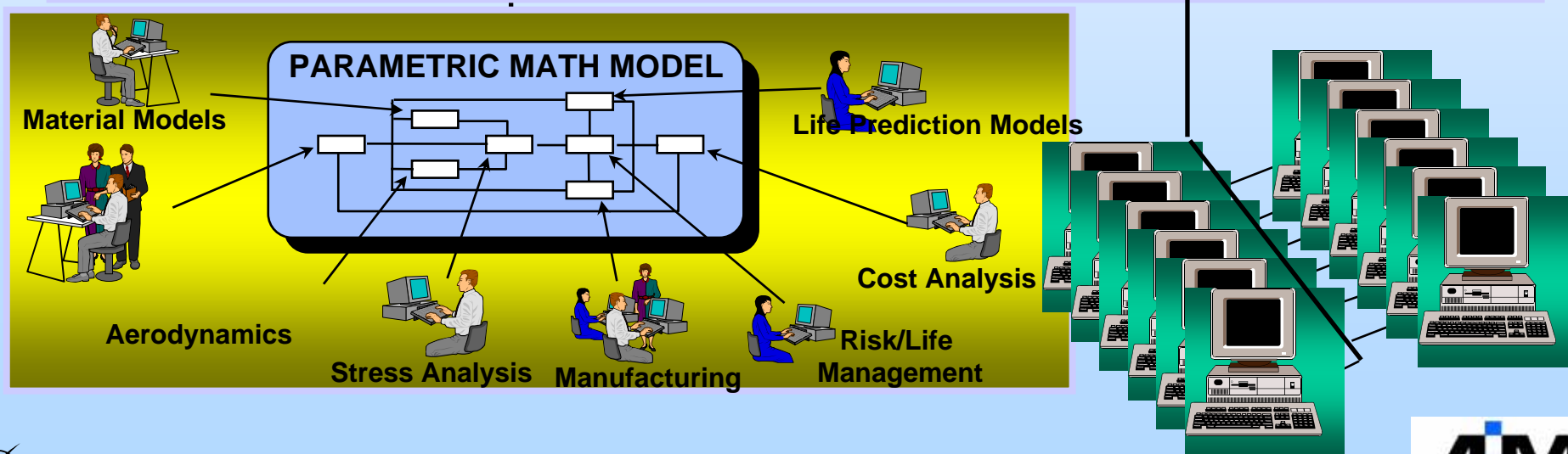
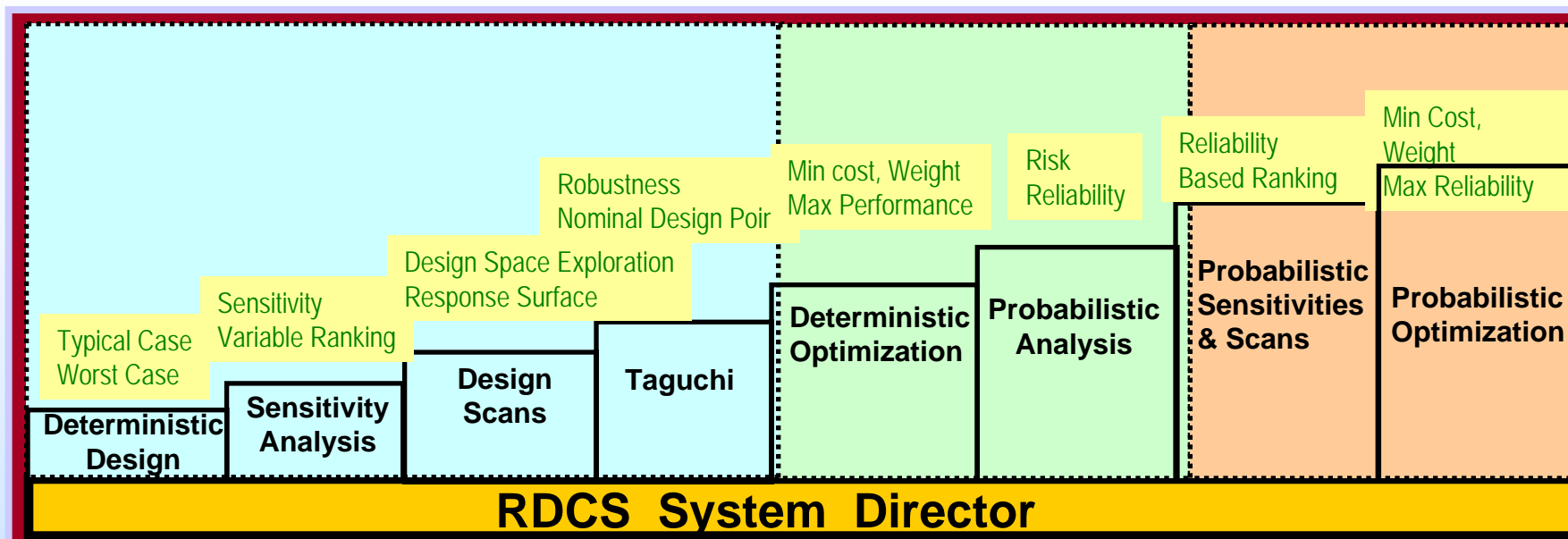
6. Alpha z vs. T at a Given Theta



(a)
AIM-C Integration 01



Robust Design Computational System



RDCS Edge of Flange Disbond Study

The Problem

Application Objective

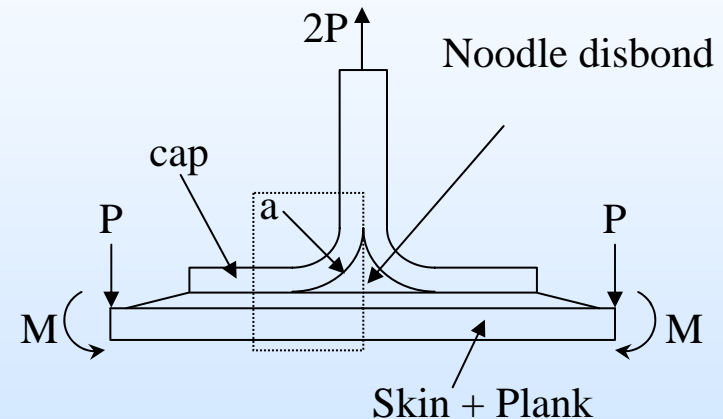
- Investigate the effect of skin-stringer panel geometric parameters on maximum moment at the flange and margin of safety for stringer pull-off
- To aid in the selection of appropriate stiffener geometry and spacing

High Level Description

- **Design variables:** Skin Thickness, Flange Thickness, Stiffener Height, Total Flange Width
- **Response Variables:** Maximum Flange Moment, Pull-off Margin
- **Solvers/Methods:** RDCS, ANSYS/LEFM

Solution Scope

- **RDCS:** Sensitivity analysis, Factorial Design Space Explorations
- **ANSYS:** Static non-linear large deflection analysis
- **Solution Cases:** 81 Large Scale FEM Solutions



RDCS Application Benefits

- **Rapid factorial design calculations for external ANOVA study and response surface with significant cycle time reduction**
- **ANOVA helps identify critical factors and interactions**
- **Accurate surrogate response surface model helps simplify the design process**



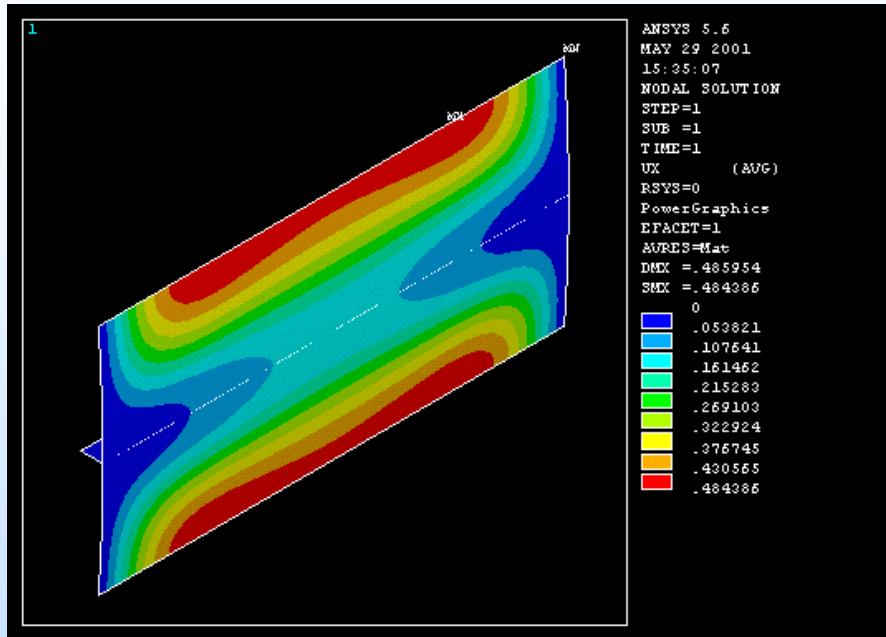
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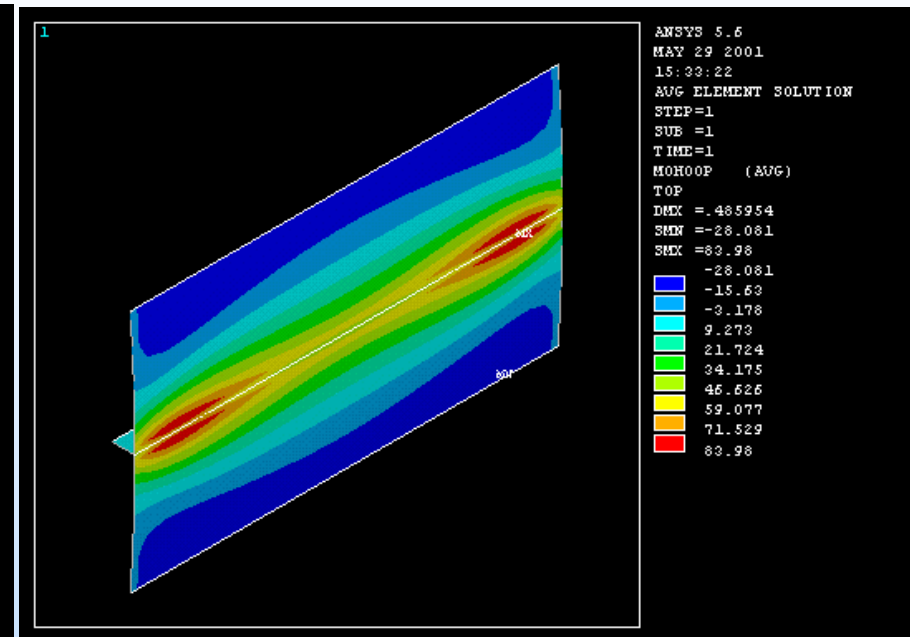


RDCS Edge of Flange Disbond Study

The Problem



Internal Pressure (or postbuckling) create large pillowing deflections between stringers

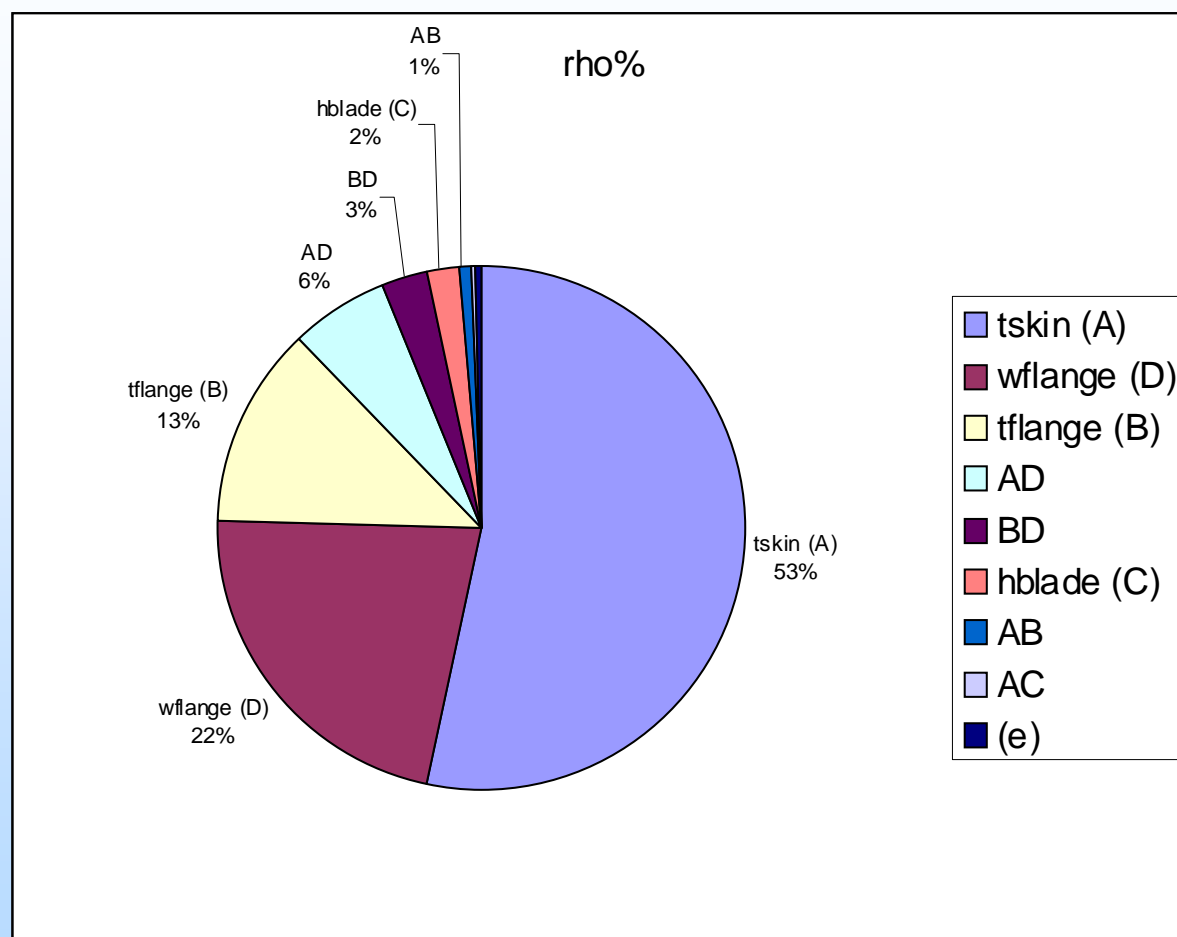


These deflections create high moments at the skin-to-stringer bondline. The loads don't vary tremendously along the length – can be analyzed as a 2D problem using the maximum loads (conservative)



RDCS Edge of Flange Disbond Study

ANOVA Results

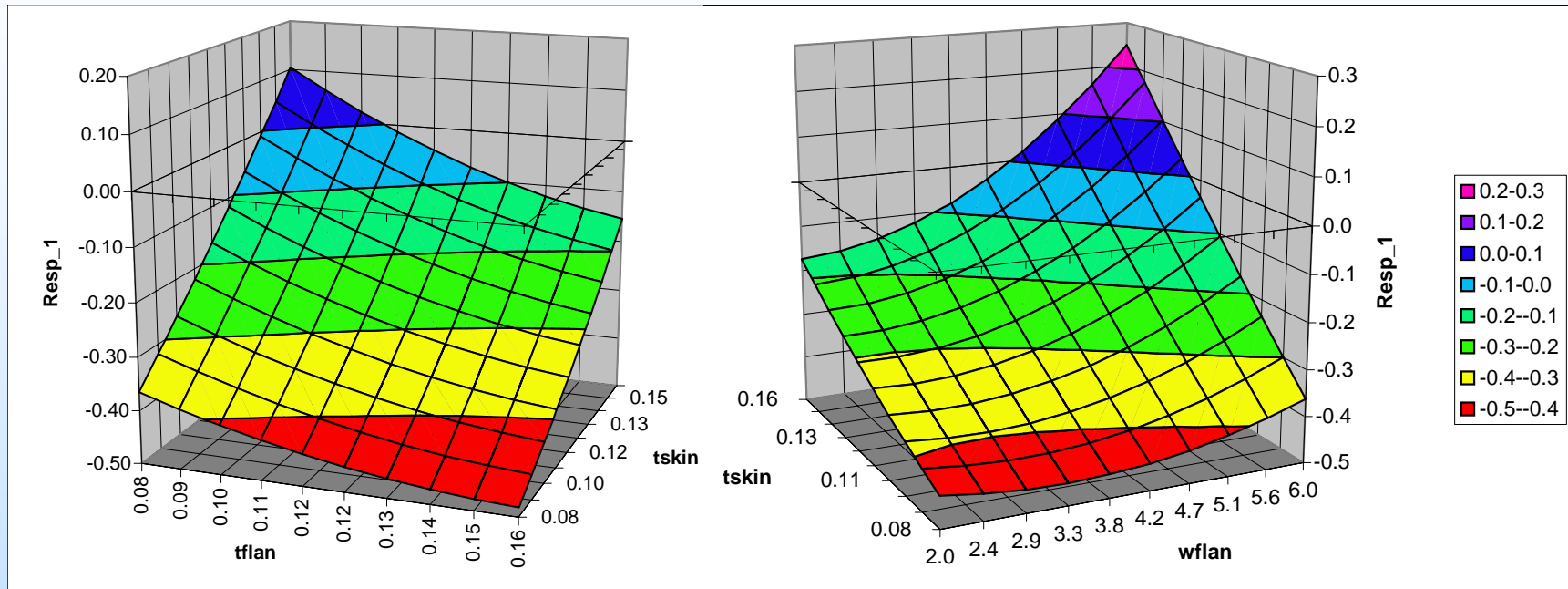


The major influences are skin thickness, flange width, flange thickness, and their interactions



RDCS Edge of Flange Disbond Study

Interaction Results

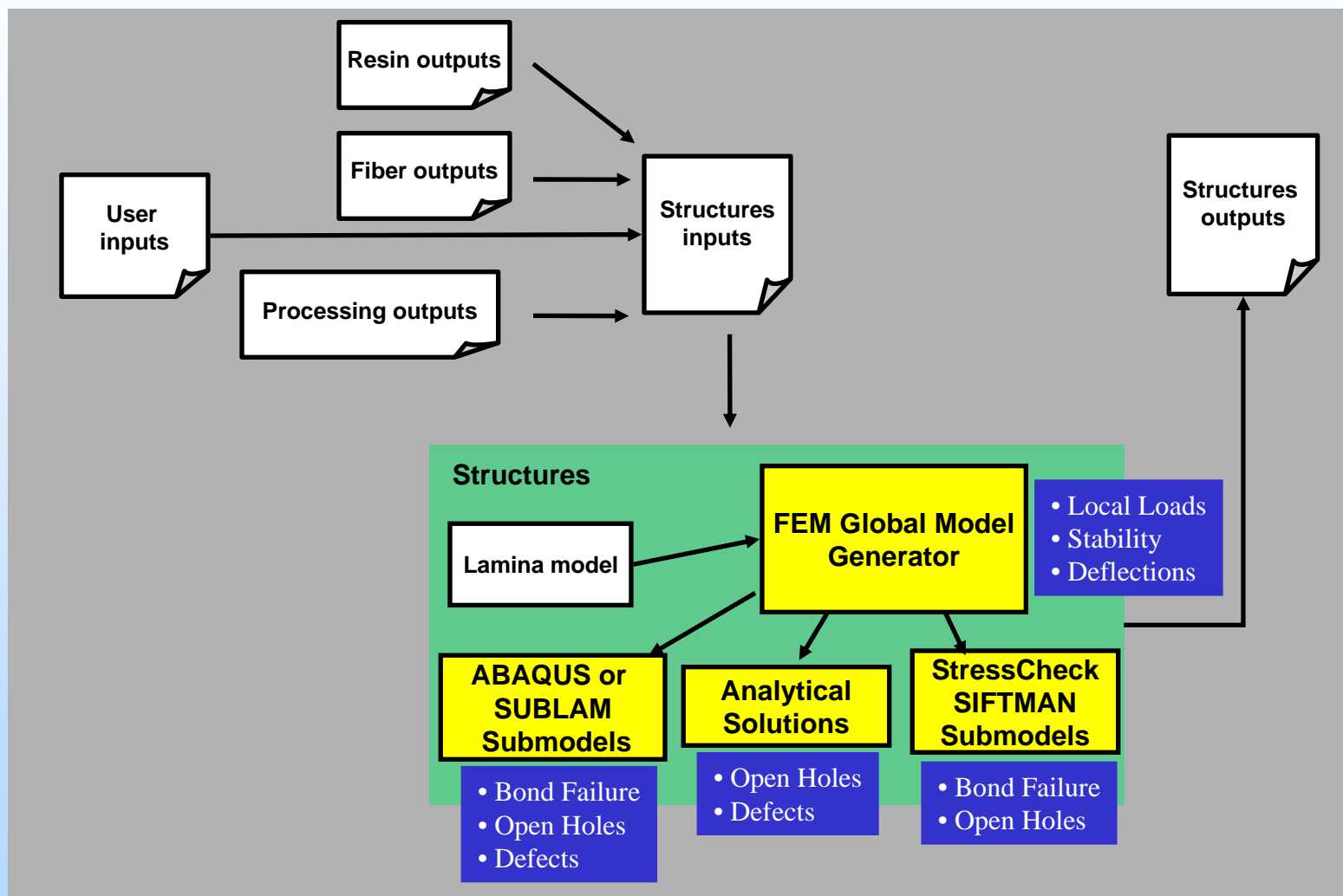


- Best edge-of-flange peel margin of safety is when skin is thick and flange is thin
- Flange width has a much greater effect on the margin when skins are thick. The effect is highly nonlinear.



Schematic of Design/Analysis Framework

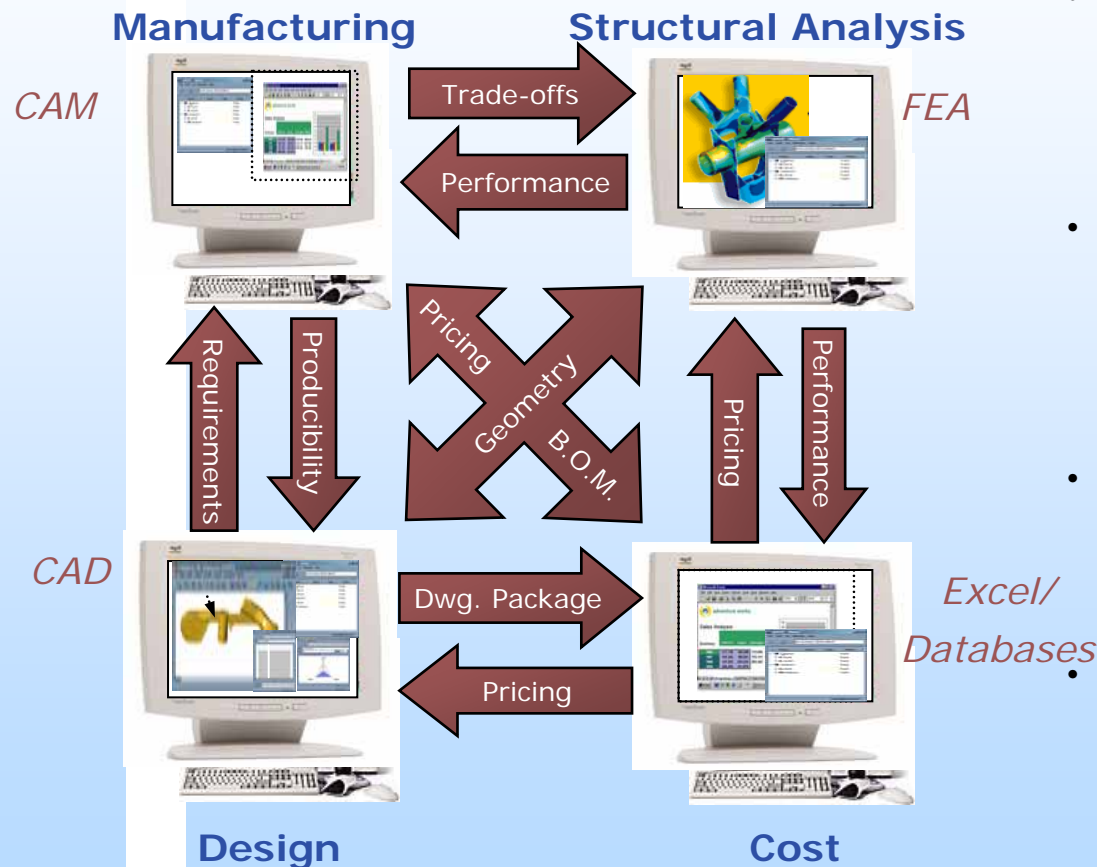
Long term Strategy





The Oculus Integration System

COTM: A Plug & Play Modeling Environment



- **Integrates Data and Software Applications on-the-fly**
 - Drag & Drop, Plug & Play
 - Simple to create, modify, manage, maintain
- **Enables Real-time data sharing between applications**
 - Secure
 - Controlled
 - Intra/Internet
- **Platform Independent**
 - Distributed
 - Neutral to Platforms and Applications
- **Increases Value of Previous Investments**
 - Software
 - Hardware
 - Networks



Oculus Models

CO Engine at flanagan - CO

File Edit View Module Navigate Bookmarks Manage Window Help

dome://207.106.229.67:3663

CO Engine at flanagan

Name	Active	Policy			
AIM (Structures Module)		View			
Open Hole	active	View			
Point Stress	active	View			
Run_Server	active	View			

Engine description
CO Engine, brought to you by Oculus

Open Hole - CO

File Edit View Module Navigate Bookmarks Manage Window Help

dome://207.106.229.67:3663/AIM (Structures Module)/Open Hole

Open Hole

Name	Value	Units	Policy				
Variables			Private				
Lamina_Batch			Private				
Laminate_MaxStrain			Private				
Dashboards			View				
Problem Definition			Public				
Process Variables			Public				
Fiber Props @ Operating Temp			Public				
Resin Props @ Operating Temp			Public				
SIFT Properties			Public				
Maximum Strain Failure Criteria			Public				
Hashin Failure Criteria			Public				
Phase Average Failure Criteria			Public				
Run	Lamina_Ba...		Execute				
Laminate Relations			Private				
Lamina Relations			Private				
Lamina Variables			Private				
Laminate Variables			Private				
Laminate_Hashin			Private				
Laminate_PhaseAvg			Private				

Currently 3 models on MSC's Engine

Functional modules within the Open Hole model



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Oculus Dashboards

Problem Definition - CO

File Edit View Module Navigate Bookmarks Manage Window Help

Home://207.106.229.67:3663/AIM (Structures Module)/Oper

Problem Definition Public

Lamina method 1 unitless

Operating Temp 70 degree fahrenheit z offset 0.000E0

Number of plies 8 unitless

Layup Info

	0	1	2
0	1	0.008	45
1	1	0.008	0.000E0
2	1	0.008	-45
3	1	0.008	90
4	1	0.008	90
5	1	0.008	-45
6	1	0.008	0.000E0
7	1	0.008	90

{Material ID (1), Thickn

of Load Sets 3 unitless

	0	1	2	3	4
0	0.125	640	0.000E0	0.000E0	0.160
1	0.125	640	0.000E0	0.000E0	0.160
2	0.125	640	0.000E0	0.000E0	0.160
3	0.000E0	0.000E0	0.000E0	0.000E0	0.000E0

Open Hole Info

Run

Hashin Failure Criteria - CO

File Edit View Module Navigate Bookmarks Manage Window Help

3663/AIM (Structures Module)/Open Hole?Dashboards/Ha

Hashin Failure Criteria Public

Theta = 0 degrees

	failedPlyMatrix1	loadFactorMatrix1
1	1 unitless	44.857 unitless
4	4 unitless	32.560 unitless
7	7 unitless	104.658 unitless

Theta = 45 degrees

	failedPlyMatrix2	loadFactorMatrix2
4	4 unitless	7.459 unitless
3	3 unitless	9.915 unitless
1	1 unitless	1066.754 unitless

Theta = 90 degrees

	failedPlyMatrix3	loadFactorMatrix3
4	4 unitless	4.490 unitless
1	1 unitless	7.378 unitless
8	8 unitless	88.083 unitless

Input dashboard:
Problem Definition

Output dashboard:
Hashin failure info for
OHT



Structures - Hat Stiffened Panel (HSP)

Design/Analysis Procedure

- HSP is a large-scale, complex, detailed design problem
Draw on multiple AIM-C modules.
- Accurate results require very fine grid mesh or small element sizes
Problem is too large in scale to model with one finite element
Thus, a combination of global and local models will be used.
- Submodeling or local modeling capture design details and mfg. defects
Submodels are finely meshed cutouts of the global model.
Global Model results feed the submodels



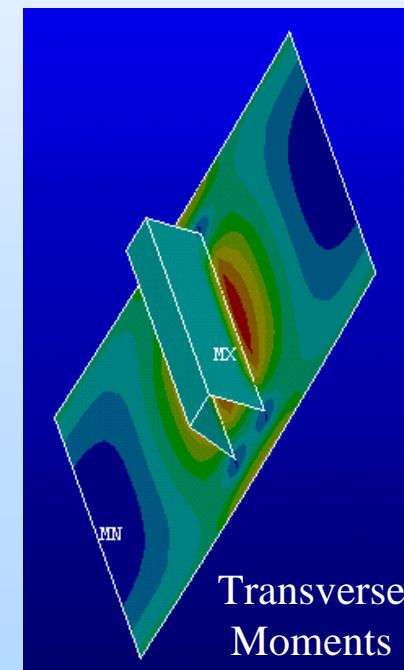
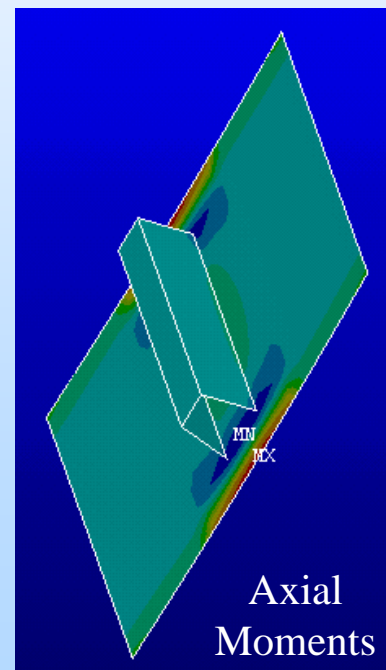
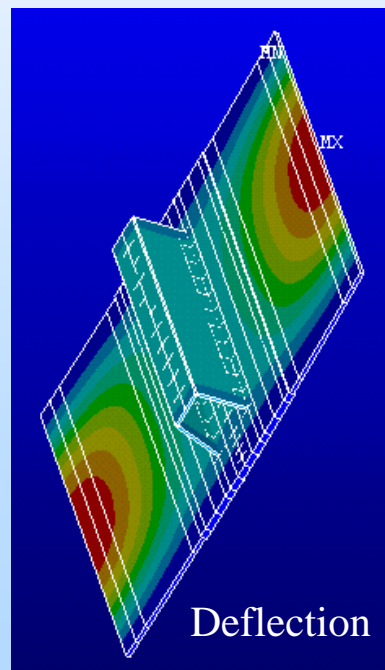
Parametric Global Structures Module

What do you gain from the Global Models?

- Accurate Load Distribution – Failures depend on correct local loads
- Identification of Local Model Requirements
- Easy assessment of Multiple Load Cases
- Rapid Design Iteration – Ability to perform quick geometry trades
- Assessment of Global Failure Modes – Stability, Deflection

How do they work? Demonstration using a simple one-bay hat model in ANSYS

- Model and run a baseline...Hat under pressure (Linear)

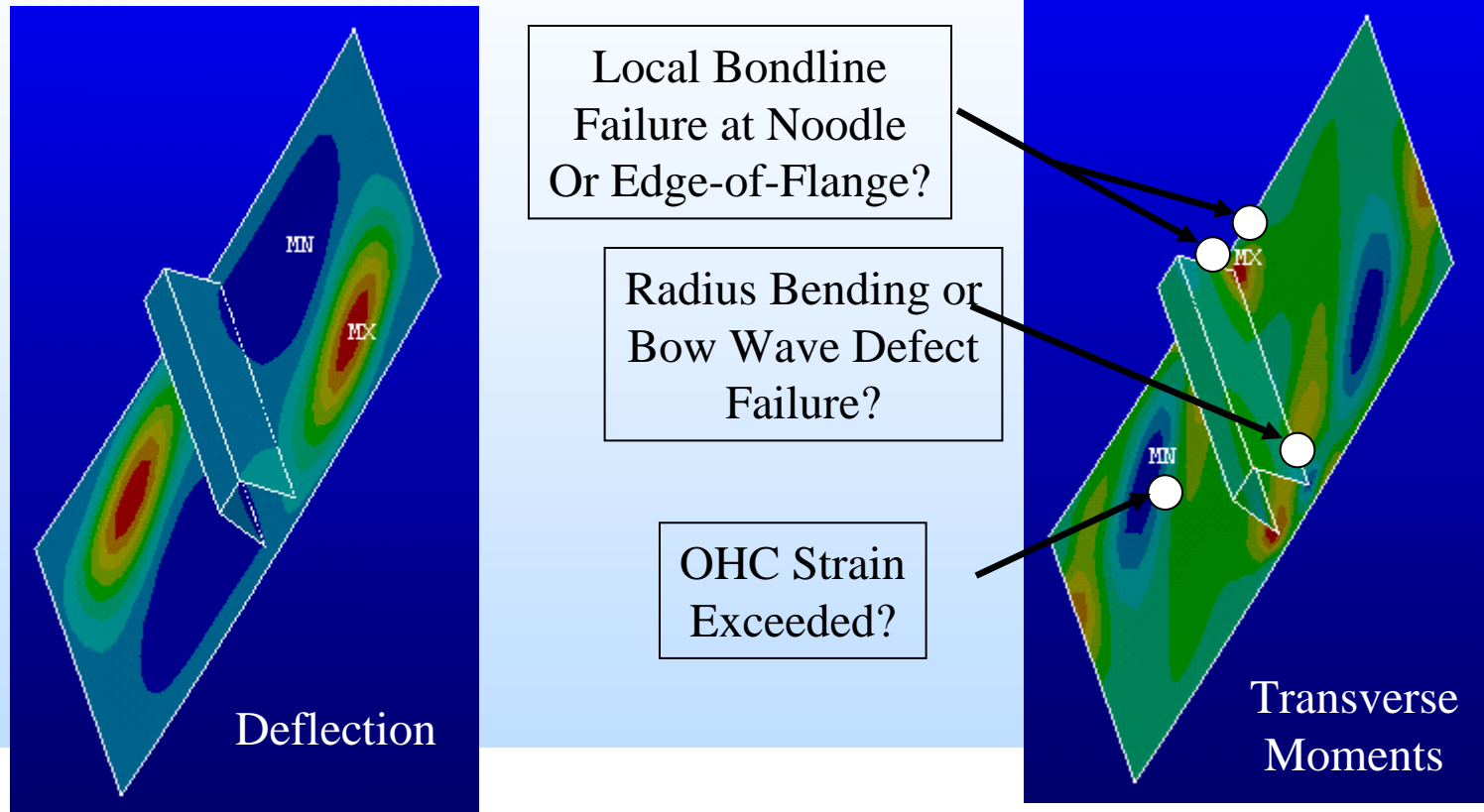




Parametric Global Structures Module Demonstration

Global and Local Failure Modes

Another load case...Hat under in-plane shear ($2500\mu\epsilon$)
(Nonlinear Large Deflection Solution)



- Not buckled yet, but significant bending due to the eccentricity of the stiffener is beginning to form the first buckling mode shape. Max deflection is 0.034". Okay for Aero?

- Identify local model requirements.



Local Models

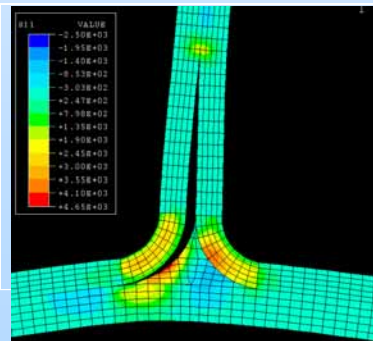
Design Details

Local Models are used to perform detailed analysis in an area of interest, usually
A potential failure location – often an area of high loading near a structural discontinuity

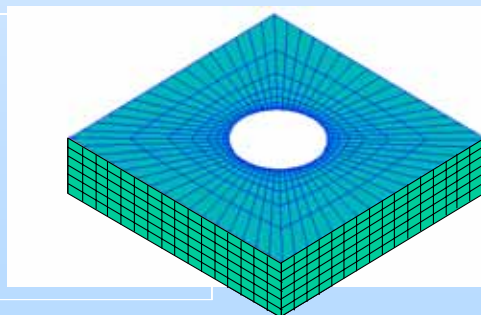
Two kinds of Local Models:

1. Design Details – a designed-in structural feature (e.g., Open Hole, Edge of Flange)
2. Mfg. Defect – an undesired “feature” produced as a side-effect of the manufacturing process (e.g., waviness, delamination, porosity)

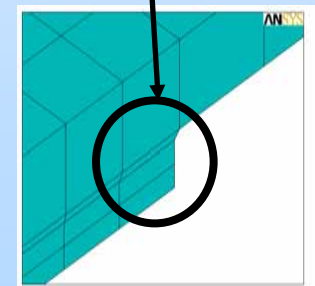
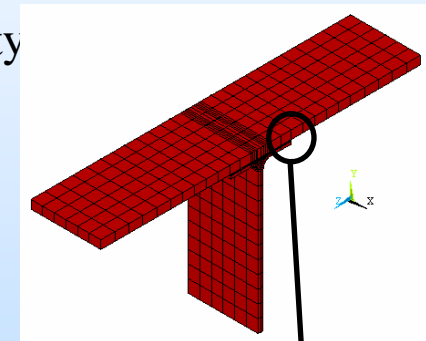
Local Models for Design Details:



“Noodle” Models



Open Hole Models

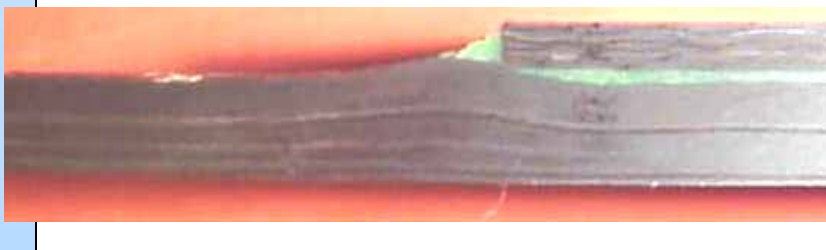


Edge-of-Flange Models

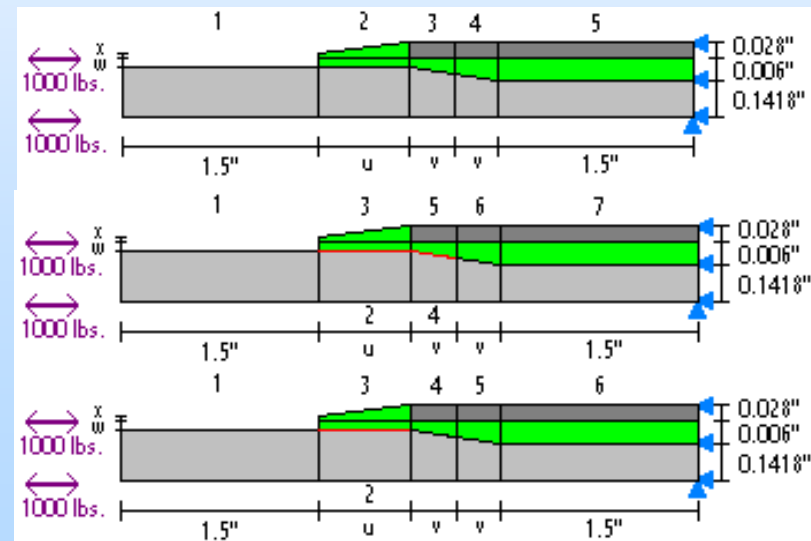


Bow Wave Defect Analysis Using SUBLAM Linked to RDACS

- SUBLAM was incorporated into RDACS to demonstrate the concept of creating a suite of “defect analysis handbooks” to be inserted in the AIM-C CAT.
- Full factorial design space scans were conducted to compute the sensitivity of local stresses and energy release rates under tensile and compressive loads to four geometric variables.



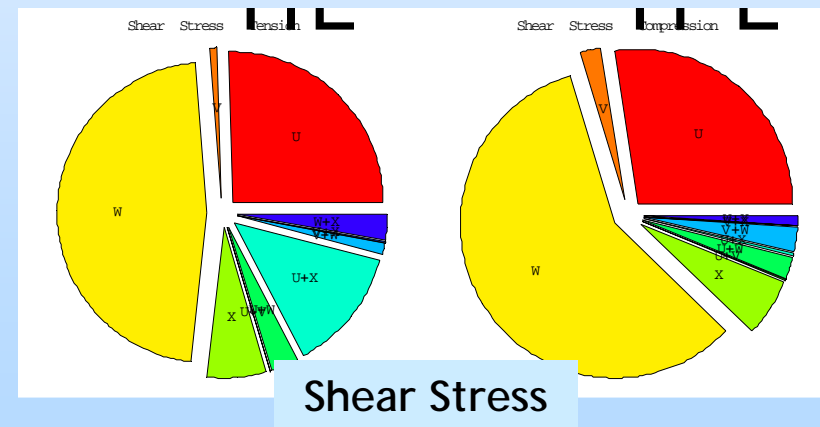
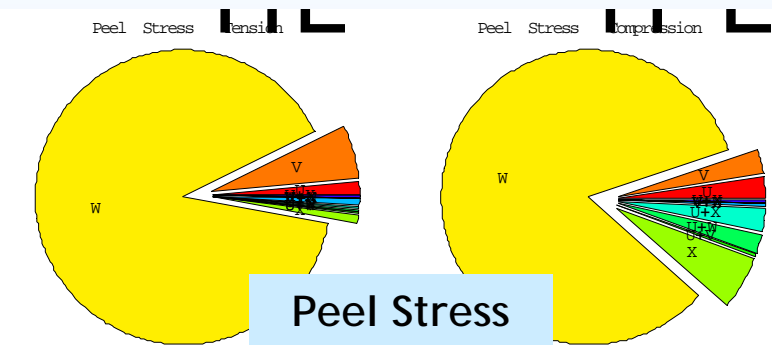
Variable		Lower Limit	Center Value	Upper Limit
u	Resin pool length	0.05"	0.175"	0.3"
v	Bow-wave length	0.05"	0.125"	0.2"
w	Adhesive thickness	0.0005"	0.00325"	0.006"
x	Resin pool height	0.0005"	0.01425"	0.028"





Bow Wave Defect Analysis – Sample Results

- Peel and shear stresses driven by adhesive thickness and resin pool length.
- Relative contributions depend only slightly on whether load is tensile or compressive.
- Some significant two-way interactions for shear stress, viz., resin pool length and height.
- Bow wave length not a big driver for range studied.



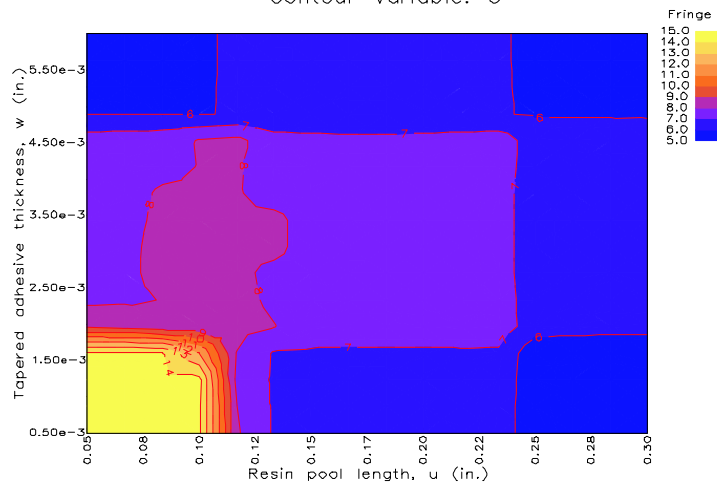


Bow Wave Defect Analysis – Sample Results

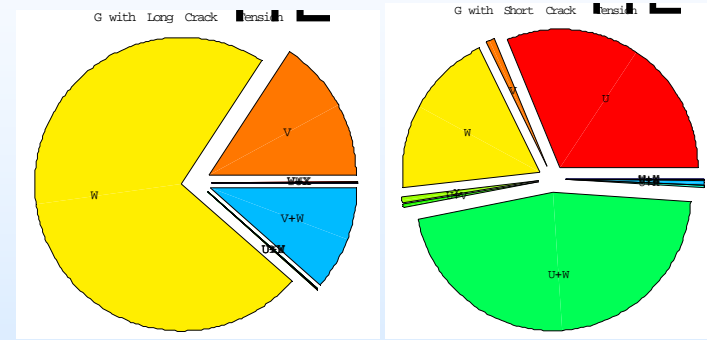
- Contributions to ERR (G) strongly dependent on whether load is tensile or compressive and initial crack (defect) size.

Design Point Set: Tension_short_crack

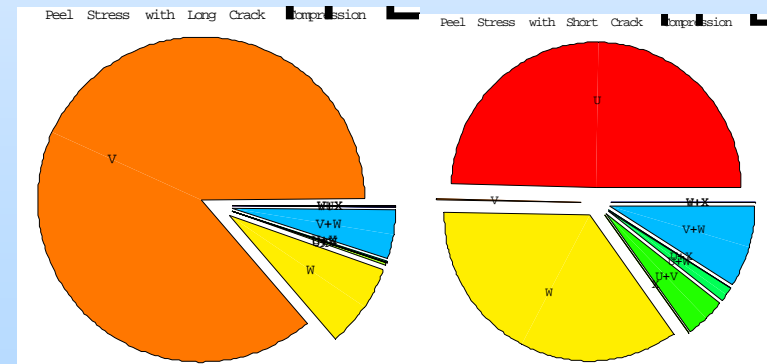
Contour Variable: G



G (in-lbs/in²) for tensile load as a function of initial defect size and adhesive thickness.



Tension



Compression